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EXPERIMENTAL INVESTIGATION OF CRANK SHAFT WITH CRACK OF A DIESEL ENGINE

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ABSTRACT

Today, a number of small power plants base on Diesel engines are being installed. Such units are typically multi cylinder engines and failure in any one of the engines could lead to shutting down of the entire plant. Cracks in crankshaft are one of the many causes for failure of such engines, which if not detected early could result in catastrophic failure. Hence, analysis of such system swould give an insight into the modes of failure of the various parts of the system. The present work was prompted by a failure that occurred in an eighteen cylinder V- engine driven Power plant. The main objective of thisstudyis to evaluate the response of a cracked crankshaft of a four stroke 18 V diesel engine. It is also proposed to determine transient response of the cracked crankshaft so that it can be compared with the response of the crankshaft without crack. It is proposed to use Finite element analysis to find the transient response of the crankshaft with and without crack. The crankshaft has been modeled using the 3D modeling software Pro/E. The model was then imported & meshed using 3D tetrahedral elements using HYPERMESH software. The meshed model was then imported to the ANSYS software to find out the transient response.

KEYWORDS: *Cranks, Failure, Engine, Finite element analysis, ANSYS & HYPERMESH*

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INTRODUCTION

IC engine based diesel power plants of 5 – 50 MWe capacity are installed in several parts of the country. To augment the energy requirements either for base load or for peakload. Continuous operation of such installations is absolutely necessary to prevent fluctuation on the grid. The IC engines used in such power plant are large size and designed to run for a life of more than 15 years. The crankshaft is a critical component with a complex geometry in the engine, which converts the reciprocating displacement of the piston to a rotary motion with a four link mechanism. The main function of the crankshaftis to give smooth rotary output. It is the heart of the Internal Combustion Engine. In case of a crankshaft failure, the cost of the repair includes not only that of the crankshaf titself, but also the cost of other parts of the engine affected by the crankshaft failure and the lengthy time period required for repair, mainlybecause of the crankshaft location inside the cylinder. Figure 1 shows the location of a crankshaft in an engine [4].

The most common cause of crankshaft failureis fatigue. In order for fatigue to take place, a cyclic tensile stress and a crack initiation site are necessary. A crankshaft experiences large forces from gas combustion. This force is applied to the top of the piston and since the connecting rod connects the piston to the crankshaft, the force will be transmitted to the crankshaft. The magnitude of the force depends on many factors which consist of

crank radius, connecting rod dimensions, weight of the connecting rod, piston, piston rings, and pin. Combustion and inertia forces acting on the crankshaft cause two types of loading on the crankshaft structure; torsional load and bending load [1].

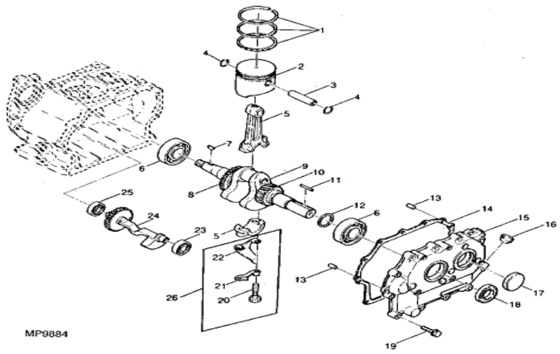

Figure 1: Exploded View of a Single Cylinder Engine Showing the Crank Shaft

Due to these loads fatigue cracks occur frequently at the location of the crankp in-web fillet region, the edge of the oil aperture in crank pin, surface of the main journal, etc. The fracture surfaces on a crankshaft which failed due to fatigue.

OBJECTIVES

To study the vibration behavior of a multi throw crankshaft with crack and its influence on the transient response of the shaft. The transient response of the crankshaft with and without cracks will be compared for better insight into the detection of onset of cracks.

Usually the physical dimensions, boundary conditions and the material properties of the structure play important role for the determination of its dynamic response. Their vibrations cause changes in dynamic characteristics of structures. In addition to this, presence of a crack in structures modifies its dynamic behavior.

CRANKSHAFT MODELING WITHOUT CRACK

The 3D cad model of the crankshaft was createdwith the data given in the Table 1. The full model of the crankshaft with counter weight was prepared as shown in the figure 2. The crankshaft has many small fillets and fine oil hole. Consideration of these features in the modeling process, causes the finite element mesh of crankshaft to become very dense and the number of nodes increases. This results in increases in the error and solving time. Hence, the simplified 3D model of crankshaft was modeled using Pro E software. In this simplified model, the chamfers with radius less than 5mm and the oil holes were ignored.

Table 1: Crank Shaft Dimension

SI. No	Parameters	Values
1	CrankshaftLength (mm)	10522
2	CrankpinDiameter (mm)	450
3	Main Journal diameter	450
4	Density, ρ (Kg/m^3)	7900
5	CounterWeight mass	600
6	Crack location (l)	Variable
7	Crack width (c)	5 mm
8	Crack depth (a)	variable

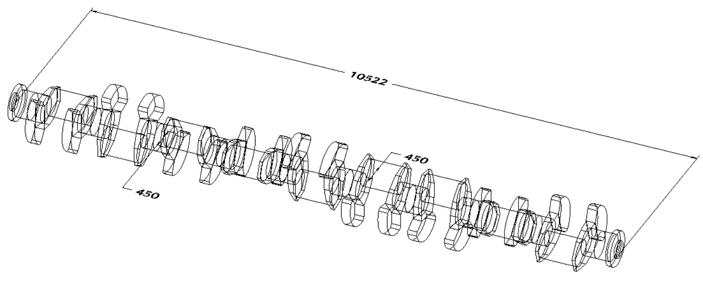

Figure 2: 3-D CAD Model of the Crank Shaft with Counter Weight

FINITE ELEMENT MESH GENERATION

The basic idea behind the finite element analysis is to make calculations at only limited points and then interpolate the result for the entire domain. Any continuous system has infinite degrees of freedom. Finite element method reduces the degree of freedom from infinite to finite with the help of meshing. Geometry cleanup should be made before meshing the model. Model cleanup removes the free edges, scarlines and duplicate surfaces. The 3D crankshaft model created in the PRO E was imported to the meshing software HYPERMESH. After geometry cleanup the model was meshed with 3D tetrahedral element. Crankshaft with counter weight was meshed with 100000 elements. Figure 3 shows the meshed model of the crankshaft with the counter weight.

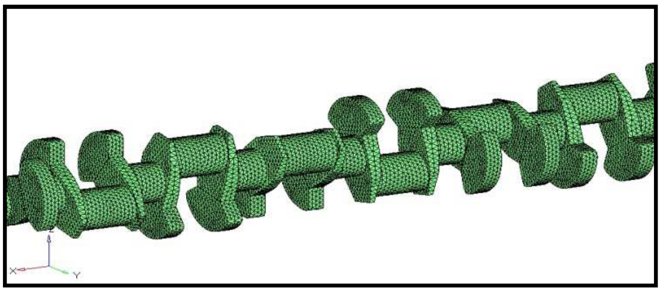

Figure 3: Meshed Model of the Crank Shaft with Counter Weight

EXPERIMENTATION

Natural Frequency of Crankshaft With and Without Crack

The detailed procedure of crankshaft modeling was explained in Chapter 3. The results obtained from ANSYS have been presented in this chapter. The vibration characteristics of crankshaft were obtained using modal analysis. The first six modal parameters of the crankshaft have been listed in Table 2. From the simulation results and the vibration modal shapes, the lowest frequencyis10.869 Hz, and with the increase of modal order, the frequencyincreases accordingly. Table 2 lists the natural frequencies of a crankshaft with and without crack with different crack ratios y started started from 0.08 to 0.8 at a dimensionless crack location x equal to 0.6.

From Table 2 it is noted that the natural frequency of the crank shaft with crack is lower than the natural frequency of the crank shaft with crack. Reduction in the natural frequency of the cracked crank shaft is due to the stiffness reduction by the presence of crack. Natural frequency reduces substantially in both 3D cut and element kill method. The difference between natural frequencies obtained by this two method within the range of -4% to 0.2%. Figures 4(a) to

4(c) show the mode shape of the crankshaft with and without the crack. First and third modes are the bending modes, while the fifth mode is a torsion mode.

Table 2: Natural Frequency at Different Crack Ratio (y=a/w), x=l/L=0.6

Crack Ratio	Method	Mode1	Mode2	Mode3	Mode4	Mode 5	Mode 6
No crack		10.869	11.63	30.167	33.771	50.955	56.244
0.08335	3D cut	10.862	11.607	30.119	33.748	50.844	56.193
	element kill	10.844	11.597	30.085	33.686	50.790	56.135
0.1667	3D cut	10.830	11.599	30.098	33.645	50.791	56.167
	element kill	10.829	11.595	30.081	33.659	50.781	56.133
0.250	3D cut	10.788	11.586	30.080	33.577	50.775	56.133
	element kill	10.797	11.583	30.045	33.583	50.728	56.082

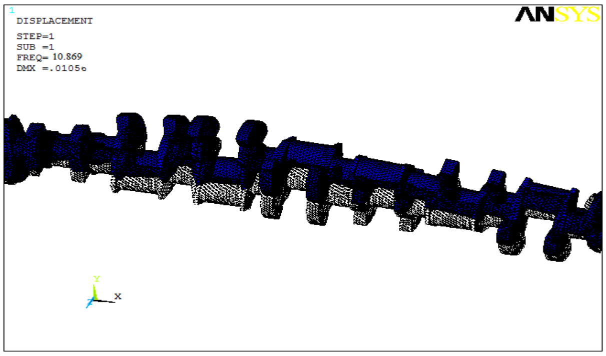

Figure 4(a): 1st Mode-No Crack

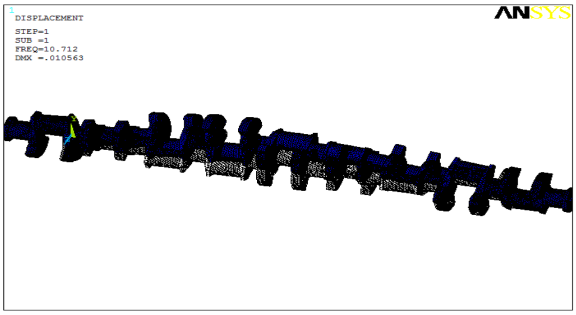

Figure 4(b): 1st Mode-3d CutY= 0.334 & X=0.6

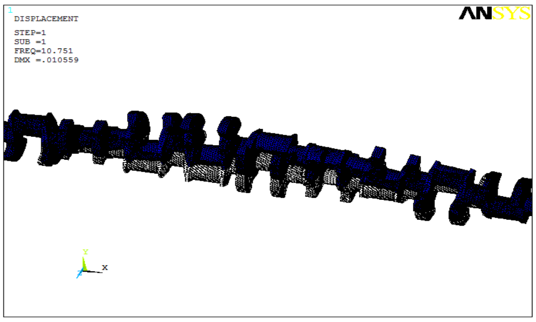

Figure 4(c): 1st Mode-Element Kill

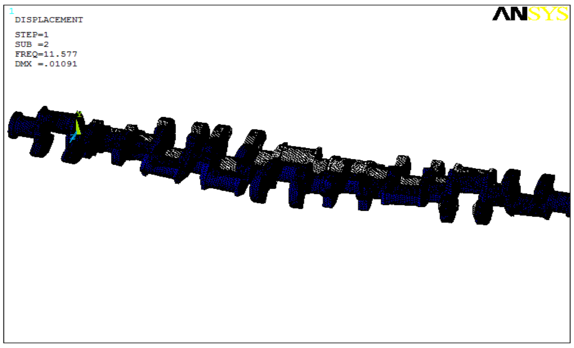

Figure 5(a): 2nd Mode-3d CutY= 0.334 & X=0.6

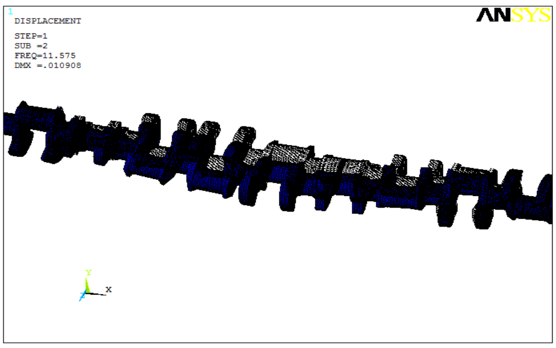

Figure 5(b): 2nd Mode-Element Kill

CONCLUSIONS

The present work deals with the analysis of crankshafts with & without cracks, the results obtained from the vibration analysis of the crankshaft with and without cracks under three conditions have been discussed in chapter IV. From the results it is observed that the presence of crack in the crankshaft alters the local flexibilities and thus there is reduction in the natural frequency of the system. Three cases have been studied as outlined below:

- Effect varying crack ratio for constant crack location

There is a continuous reduction in the natural frequency with the increase in the crack depth. The change in natural frequency is moderate upto a crack ratio of 0.334, and beyond this change in natural frequency is drastic. The reduction in the natural frequency is around 26 % for the fundamental mode. For third and fifth mode the reduction in the natural frequency is around 15% and 6% respectively. Comparing these results the presence of cracks in the crankshaft affects the fundamental mode than the other modes.

- Effect of varying crack location for constant crack ratio

Natural frequency of the crankshaft varies with the change in the crack location. Reduction in the natural frequency is more when the crack is located at the (**x=** 0.4 and 0.5) for fundamental frequency. For other modes the natural frequency reduction is more at location x=0.3. From the graph shown in theFigure 4 it is found that the natural frequency of the crankshaft varies alternately for all modes with crack location. The lowest fundamental frequency for various crack location is found out to be 9.576 Hz.

REFERENCES

1. *B Tang. (2009). Continuum Element Method for analysing free-vibration behaviour of crankshafts, Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering 223: 49*
2. *J. A. Becerra Villanueva, F. Jimenez Espadafor, F. Cruz-Perago, M. Torres Garcia. (2011). A methodology for cracks identification in large crankshafts, Mechanical Systems and Signal Processing 25 3168–3185*
3. *A. K. Darpe, K. Gupta, A. Chawla. (2004). "Coupled bending, longitudinal and torsional vibrations of a cracked rotor" Journal of Sound and Vibration 33–60*
4. *Farzin H. Montazersadgh and Ali Fatemi. (2007). Dynamic load and stress analysis of a crankshaft, SAE international 01-0258*
5. *Jiménez Espadafor, F., Becerra Villanueva, J., M. Torres García. (2009). Analysis of a diesel generator crankshaft failure, Engineering Failure Analysis 16 2333–2341*
6. *Jian Meng, Yongqi Liu, Ruixiang Liu. (2011). Finite Element Analysis of 4-cylinder diesel crankshaft, I. J. Image, Graphics and Signal Processing. 5, 22-29*
7. *Kisa Murat and Gurel M. Arif, Free vibration analysis of uniformand stepped cracked beams with circular cross sections, International Journal of Engineering Science 45, (2007), pp.364–380.*
8. *S. P. Moghal, Dr. R. K. Behera, S. Y. Pawar (2012), Vibration Analysis Of Cracked Beam, International journal of Advanced Engineering Technology vol. III/371-377*
9. *Sadettin Orhan (2007), Analysis Of Free And Forced Vibration Of A Cracked Cantilever Beam, NDT &E international 40, 2007, 443-450.*

10. *Sachin S. Naik and Surjya K. Maiti. (2012). Solution for Coupled Vibrations of Short and Long Circular Shafts/Beams with Two Arbitrarily Oriented Open Cracks, Advances in Vibration Engineering, 11(1).*

11. *A. Tlaisi, A. Akinturk, A. S. J. Swamidas & M. R. Haddara. (2012). Crack Detection In Shaft Using Lateral And Torsional Vibration Measurements And Analyses, Mechanical Engineering Research; Vol. 2, No. 2,*

12. *Xuanyang Lei, Guicai Zhang, Jin Chen, Song Xigeng, Guangming Dong. (2007). Simulation on the motion of crankshaft with a slant crack in crankpin, Mechanical Systems and Signal Processing 21 502–513*

13. *N. Tamil Selvam, K. Arunkumar, B. R. Aravindhraj, I. Saran Raj, P. Jeyaraman, 2018. Mechanical Characterization and Comparison of Glass Fiber and Fibre Reinforcement with Aluminium Alloy (Gfraa) to Improve the Strengthening for Automotive Application. International Journal of Mechanical Engineering & Technology (IJMET) - Scopus Indexed. Volume:9, Issue:3, Pages:156-161.*